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Enhancing UI/UX Design for Children's Educational Gaming Platforms: An Integrated Multicriteria Decision Making Framework

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This study aims to enhance the User Interface (UI) and User Experience (UX) design of children's educational gaming platforms by identifying key influential factors and providing actionable insights. Recognizing the importance of digital learning tools, the research employs an Integrated Multicriteria Decision Making Framework, utilizing the Spherical Fuzzy Analytical Hierarchy process to calculate factor weights and Interpretive Structural Modelling (ISM) to unravel complex interrelationships. The findings highlight the critical importance of age-appropriate content (weight 0.139) tailored to children's cognitive abilities and developmental stages, alongside crucial components like visual design (weight 0.102), and educational content (weight 0.101). MICMAC (Matrice d'impacts croisés multiplication appliquée á un classment) analysis is carried out to classify factors into autonomous, dependent, linkage, and driving groups. Practical implications emphasize cross-platform compatibility, background score optimization, and improvements in interactivity, accessibility, safety, privacy, engagement, and feedback mechanisms. The study offers valuable insights and actionable recommendations to enhance UI/UX design, creating immersive and impactful learning experiences tailored to young users. By integrating multiple decision-making methods, the research presents a novel, structured approach to comprehensively analyze and prioritize UI/UX factors, contributing to the discourse on optimizing digital learning environments for children.

Keywords: Game design, MCDM, System design, User experience, Visual design

Introduction

Background

In recent years, the landscape of education has undergone a remarkable transformation, marked by a profound integration of technology into traditional learning methodologies.[1] This evolution is emblematic of a broader paradigm shift, where educators and technologists alike recognize the potential of technology to revolutionize the way knowledge is imparted and acquired. One prominent manifestation of this trend is the surge in educational gaming platforms tailored specifically for children. These platforms harness the immersive and interactive nature of digital environments to captivate young minds, offering a dynamic alternative to conventional teaching methods. By incorporating elements of gamification, such as rewards, challenges, and progress tracking, these platforms not only make learning enjoyable but also foster a sense of engagement and motivation among students.[2] Moreover, educational games have the flexibility to adapt to individual learning styles and pace, providing personalized learning experiences that cater to the diverse needs of learners.[3]

However, the efficacy of educational gaming platforms hinges critically on the meticulous design of their User Interface (UI) and User Experience (UX).[4] A well-crafted UI/UX design plays a pivotal role in shaping the overall educational experience, influencing factors like accessibility, usability, and engagement. A user-friendly interface ensures intuitive navigation and seamless interaction, empowering children to focus their attention on the educational content without being impeded by technical complexities. Likewise, a compelling user experience is characterized by its ability to immerse learners in meaningful and rewarding interactions, fostering a deep sense of involvement and investment in the learning process. Beyond mere entertainment value, effective UI/UX design aligns closely with pedagogical principles, integrating educational content seamlessly into the gaming experience and reinforcing key concepts through interactive exercises and challenges. In essence, the success of educational gaming platforms hinges not only on their technological sophistication but also on their ability to

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deliver an enriching and seamless educational journey that inspires curiosity, fosters learning, and cultivates critical thinking skills among young learners.

Importance of UI/UX Design in Educational Gaming Platforms

The UI and UX design of educational gaming platforms are not mere aesthetic choices but critical components that shape the learning journey of children. A thoughtfully designed interface goes beyond aesthetics; it serves as the gateway through which young learners interact with educational content. Intuitive navigation elements, clear instructions, and visually appealing graphics contribute to a seamless experience that keeps children engaged and focused on learning objectives. Moreover, a well-designed UI/UX promotes immersion by creating an environment where children can fully immerse themselves in the educational content, leading to deeper understanding and retention of concepts.

Conversely, poor UI/UX design can act as a barrier to learning, impeding children's progress and causing frustration. Cluttered interfaces, confusing layouts, and unintuitive controls can overwhelm young learners, leading to disengagement and cognitive overload. When children struggle to navigate through a poorly designed interface, their attention shifts away from learning, hindering their ability to absorb new information effectively. Therefore, developers and educators must prioritize UI/UX considerations in the development of educational gaming platforms for children. By investing in user-centered design principles, such as user research, iterative testing, and feedback mechanisms, developers can create experiences that not only captivate children's interest but also optimize learning outcomes. In doing so, educational gaming platforms can fulfill their potential as powerful tools for fostering curiosity, exploration, and lifelong learning among children.

Challenges in UI/UX Design for Children's Educational Gaming Platforms

Designing UI and UX for children presents a multifaceted challenge that necessitates a nuanced understanding of their cognitive capabilities, preferences, and developmental stages.[5] Unlike adults, children possess distinct traits such as limited attention spans, fluctuating levels of digital literacy, and unique sensory perceptions, which significantly impact their interaction with digital interfaces. Furthermore, educational gaming platforms must navigate through the complexities of catering to diverse age groups, learning styles, and cultural backgrounds, adding layers of complexity to the design process.[6]

To address these challenges effectively, designers must adopt a multidimensional approach that accounts for the diverse factors influencing children's interaction with digital interfaces. Firstly, the UI/UX design should prioritize simplicity and clarity, employing intuitive navigation systems, concise instructions, and visual cues to guide children through the platform seamlessly. Given children's varying levels of digital literacy, interfaces should be designed with accessibility in mind, ensuring that even young users can navigate through the platform independently. Secondly, designers must recognize the importance of engagement and interactivity in capturing children's attention and maintaining their interest. Incorporating elements of gamification, such as rewards, challenges, and interactive feedback, can enhance motivation and promote active participation in the learning process. Moreover, the design should accommodate for diverse learning styles, offering flexibility in how educational content is presented and interacted with to cater to individual preferences and needs. Lastly, cultural sensitivity and inclusivity should be integral considerations in UI/UX design for children. Educational gaming platforms must reflect the diversity of their user base, incorporating culturally relevant content, characters, and imagery to ensure that all children feel represented and included. By embracing these principles and adopting a child-centric approach to UI/UX design, developers can create educational gaming platforms that not only captivate young learners but also empower them to explore, learn, and grow in a digital world.

Multicriteria Decision Making (MCDM) in UI/UX Design

Multicriteria decision making (MCDM) methodologies provide a structured approach to assess and rank design alternatives by taking into account various criteria or objectives.[7] In the realm of UI/UX design, where multiple factors such as usability, accessibility, aesthetics, and educational effectiveness influence the overall quality of the design, MCDM offers a valuable framework for designers to make informed decisions. By systematically analyzing and weighing these criteria, designers can identify the most suitable design alternatives that align with the project goals and user needs.[8,9]

One of the strengths of MCDM lies in its ability to handle complexity and ambiguity inherent in design decision-making. For instance, integrating advanced techniques like the Spherical Fuzzy Analytic Hierarchy Process (AHP) allows designers to model and prioritize criteria with uncertain or imprecise information[10], such as subjective user preferences or qualitative assessments of aesthetics. By incorporating fuzzy logic, AHP accommodates the inherent uncertainty in human judgment, providing a more realistic representation of decision-making processes in UI/UX design.

Furthermore, techniques such as Interpretive Structural Modelling (ISM) enable designers to map out the interrelationships among different design criteria, helping identify key drivers and dependencies that influence the overall design outcome.[11] By visualizing the hierarchical structure of criteria and their interactions, ISM facilitates a deeper understanding of the design problem and aids in the identification of critical factors that warrant special attention. This holistic approach not only enhances the robustness of decision-making processes but also ensures that designers consider the broader implications of their design choices on the overall user experience.

Research Gaps/Objectives

Despite the increasing popularity and importance of educational gaming platforms for children[12], there remains a notable gap in the literature concerning the comprehensive analysis and prioritization of factors influencing the user interface (UI) and user experience (UX) design in this context. While previous studies have explored various aspects of UI/UX design and educational gaming separately, there is a lack of integrated approaches that systematically analyze and prioritize key factors shaping the UI/UX experience specifically for children's educational gaming platforms. Furthermore, existing research often focuses on individual components such as visual design[13], educational content[14], or usability[15], without considering the holistic interplay of these factors and their hierarchical significance within the UI/UX design framework. This gap highlights the need for a novel methodology that integrates multiple criteria decision-making methods to provide a comprehensive understanding of the factors influencing UI/UX design in educational gaming platforms tailored to children's needs and developmental stages.

Moreover, while some studies may touch upon the importance of age appropriateness[16] and content relevance in educational gaming, there is a lack of in-depth analysis on how these factors interact with other elements such as visual design, usability, and safety considerations to optimize the overall user experience. Addressing this research gap is crucial for informing the development of more effective and engaging educational gaming platforms that cater to the unique needs of children while promoting meaningful learning experiences.

Therefore, this research aims to bridge the gap by offering a systematic analysis and prioritization of key factors influencing UI/UX design in children's educational gaming platforms through the application of an Integrated Multicriteria Decision Making Framework. By identifying and prioritizing these factors, this study aims to provide actionable insights for improving the design and development of educational gaming platforms to better serve the needs of young users and enhance their learning outcomes.

Research Objectives

In light of the aforementioned considerations, this paper aims to:

1. Identify key challenges and considerations specific to UI/UX design for children.
2. Explore the application of Spherical Fuzzy AHP and Interpretive Structural Modelling, in enhancing UI/UX design.
3. Discuss the potential benefits and implications of adopting the proposed framework for improving the effectiveness and usability of educational gaming platforms targeted at children.

Materials and Methods

The present study aimed to identify factors related to UI/UX design for children's educational gaming platforms. The research methodology used in this research is given in Fig. 1. The following sections are organized according to the research methodology:

Factor Identification

Six experts consisting of three from academia and three from industry are selected for this study having minimum experience of more than 10 years. Through literature/app review and survey, a list of criteria is compiled. Experts' opinions are solicited and

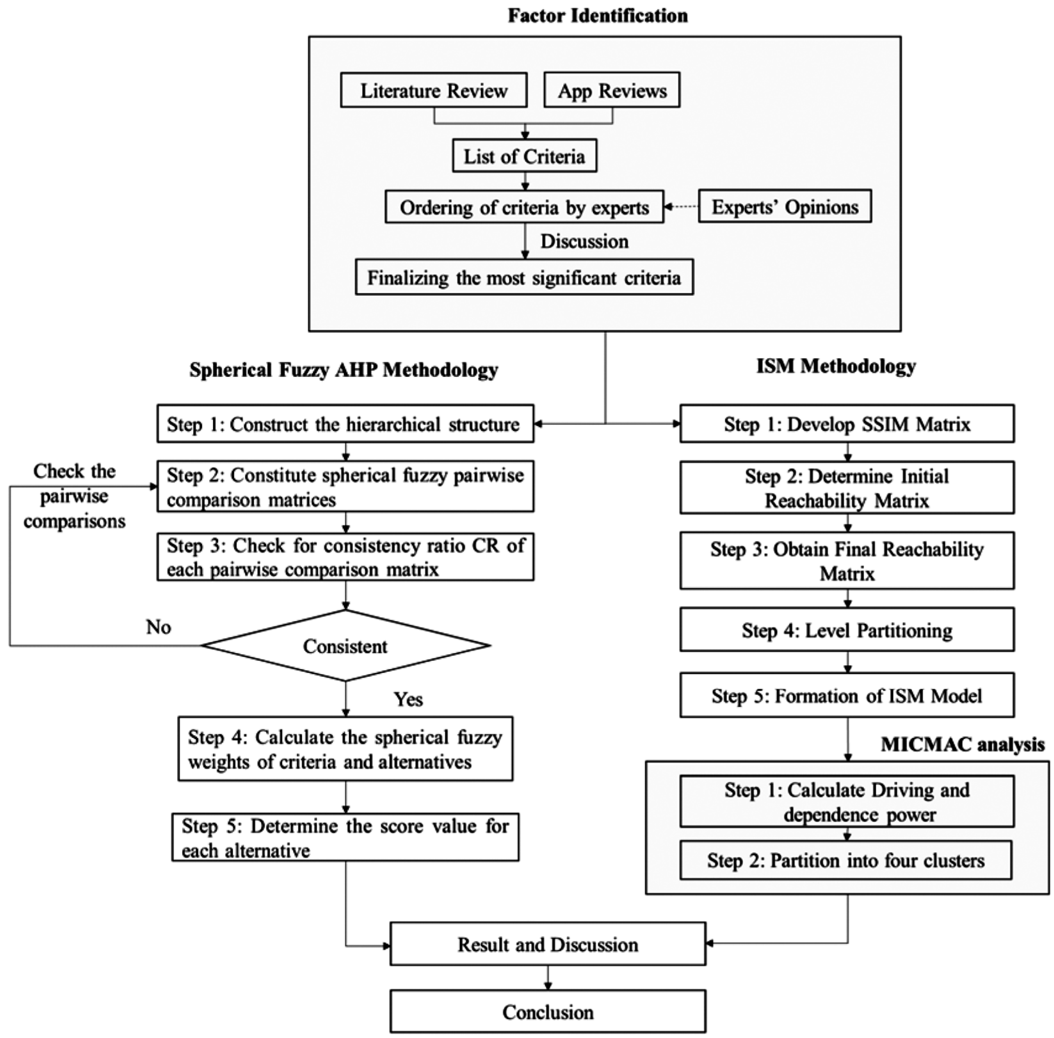

Fig. 1 — Research methodology

integrated into the discussion, facilitating a comprehensive exploration of the relative importance and interrelationships among identified criteria. Through iterative deliberations and analysis, the most significant criteria are finalized as shown in Table 1. The sample Google reviews are shown in Fig. 2 which were also used for factor identification.

Spherical Fuzzy AHP

The SF–AHP method extends the Analytic Hierarchy Process (AHP) by incorporating spherical fuzzy sets. In this research, the SF–AHP method is applied to determine the weights of the criteria.[17,18] The SF–AHP method encompasses following steps:

Step 1: Establish the hierarchical structure of the model.

A hierarchical structure consists of three levels. The top–level represents the model's goal, which is determined by a scoring index. The second level consists of n criteria that are utilized to evaluate the alternatives defined in the third level of the structure.

Step 2: Formulate pairwise comparison matrices for the criteria using spherical fuzzy judgment, utilizing linguistic terms (as demonstrated in Table 2):

$$\mathrm{SI} = \sqrt{\left|100 * \left[\left(\mu_{\tilde{A}_s} - \pi_{\tilde{A}_s}\right)^2 - \left(v_{\tilde{A}_s} - \pi_{\tilde{A}_s}\right)^2\right]\right|} \quad \ldots (1)$$

for AM, VH, HI, SM, and EI

$$\frac{1}{\mathrm{SI}} = \frac{1}{\sqrt{\left|100 * \left[\left(\mu_{\tilde{A}_s} - \pi_{\tilde{A}_s}\right)^2 - \left(v_{\tilde{A}_s} - \pi_{\tilde{A}_s}\right)^2\right]\right|}} \quad \ldots (2)$$

for SL, LI, VL, and AL

Table 1 — Details of factors identified

Criteria	Description
Educational content (C1)[19]	Incorporating educational material aligned with curriculum standards or learning objectives, providing meaningful and enriching experiences for children.
Engagement (C2)[20]	Creating features and activities that capture and maintain the attention of children, encouraging prolonged engagement with the educational content.
Accessibility (C3)[21]	Ensuring that the gaming platform is accessible to children with diverse abilities and needs, including those with disabilities or special requirements.
Age appropriateness (C4)[22]	Ensuring that the content, visuals, and interactions are suitable for the target age group of children using the gaming platform.
Interactivity (C5)[23]	Offering interactive elements such as quizzes, puzzles, or challenges that promote active participation and foster learning through hands-on experiences.
Visual design (C6)[24]	Utilizing appealing graphics, animations, and colors that are visually stimulating and conducive to learning in a playful and engaging manner.
Usability (C7)[25]	Designing intuitive and user-friendly interfaces that are easy for children to navigate and interact with, considering their cognitive abilities and motor skills.
Feedback mechanisms (C8)[26]	Implementing feedback mechanisms such as progress tracking, rewards, or notifications to provide positive reinforcement and motivate continued use of the platform.
Safety and privacy (C9)[27]	Incorporating measures to protect children's safety and privacy online, including parental controls, secure data handling, and age-appropriate content filtering.
Cross-platform compatibility (C10)[28]	Ensuring compatibility across various devices and platforms to reach a broader audience of children and accommodate different technological preferences.
Background score (C11)[29]	It refers to the continuous playing of music or audio tracks in the background while children engage with the educational content or gameplay. This music is intended to enhance the overall atmosphere, mood, and immersion of the gaming experience without being the focal point of attention.

Kids' games come in various forms, including board games, video games, outdoor games, and puzzles. These games are designed to be both fun and educational, helping kids develop important skills such as problem-solving, critical thinking, and teamwork.

engaging games for kids to learn problem solving and interesting logic exercises.

Easy to follow and do instructions that carries the child into variety of activities. Very good.

An educational game that my son highly recommends, very educational and easier to navigate.

This game is good but it is also very slow and for every game we need to answer a question and ti is not good because small childrens cannot answer this so please remove this type of system thankyou so much

Not very interested and its a really boring game for any age children

Fig. 2 — Sample reviews from Google play store

Step 3: It involves assessing the consistency of each pairwise comparison matrix using the classical consistency check using Eq. (3). The Consistency Ratio (CR) threshold of 10% is utilized for this purpose.

$$CR = \frac{CI}{RI} \quad \ldots (3)$$

The Consistency Index (CI) is calculated using Eq. (4):

$$CI = \frac{\lambda_{\max} - n}{n-1} \quad \ldots (4)$$

where, the maximum eigenvalue of the matrix, denoted as $\lambda_{\max}$, is used in conjunction with the number of criteria (n) in the calculation. The Random Index (RI) used in Eq. (3) is determined by considering the number of criteria utilized in the study.

Step 4: It involves obtaining the fuzzy weights for both the criteria and alternatives. The weight of each alternative with respect to each criterion is obtained using Eq. (7).

Step 5: The determination of the final ranking of the alternatives is conducted by consolidating the spherical weights at each level of the hierarchical structure. At this stage, there are two viable methods for performing the computation. The initial method involves employing the score function outlined in Eq. (5) to deconstruct the criteria weights and obtain a crisp value.

$$S(\tilde{w}_j^S) = \sqrt{\left|100 * \left[\left(3\mu_{\tilde{A}_S} - \frac{\pi_{\tilde{A}_S}}{2}\right)^2 - \left(\frac{v_{\tilde{A}_S}}{2} - \pi_{\tilde{A}_S}\right)^2\right]\right|} \quad \dots (5)$$

Table 2 — Linguistic measures of importance

Definition	(μ, v, π)	Score Index (SI)
Absolutely more importance (AM)	(0.9,0.1,0.0)	9
Very high importance (VH)	(0.8,0.2,0.1)	7
High importance (HI)	(0.7,0.3,0.2)	5
Slightly more importance (SM)	(0.6,0.4,0.3)	3
Equally importance (EI)	(0.5,0.4,0.4)	1
Slightly lower importance (SL)	(0.4,0.6,0.3)	1/3
Low importance (LI)	(0.3,0.7,0.2)	1/5
Very low importance (VL)	(0.2,0.8,0.1)	1/7
Absolutely low importance (AL)	(0.1,0.9,0.0)	1/9

The calculation of the Score Indices (SI) for each alternative is performed using Eqs (1) & (2).

Next, the normalization of criteria weights is carried out using Eq. (6), followed by the application of spherical fuzzy multiplication described in Eq. (7).

$$\bar{w}_j^s = \frac{S(\tilde{w}_j^s)}{\sum_{j=1}^{n} S(\tilde{w}_j^s)} \quad \dots (6)$$

$$\tilde{A}_{S_{ij}} = \bar{w}_j^s * \tilde{A}_{S_i} = \left(1 - \left(1 - \mu_{\tilde{A}_{S_i}}^2\right)^{\bar{w}_j^s}\right)^{1/2}, v_{\tilde{A}'_{S'_i}}^{\bar{w}'_j} \left(\left(1 - \mu_{\tilde{A}_{S_i}^2}^2\right)^{\bar{w}_j^s} - \left(1 - \mu_{\tilde{A}_{S_i}^2}^2 - \pi_{\tilde{A}_{S_i}^2}^2\right)^{\bar{w}_j^s}\right)^{1/2} \quad \dots (7)$$

The calculation of the final ranking score ($\tilde{F}$) for each alternative A_i is performed using Eq. (8):

$$\tilde{F} = \sum_{j=1}^{n} \tilde{A}_{S_{ij}} = \tilde{A}_{S_{i1}} + \tilde{A}_{S_{i2}} + \dots + \tilde{A}_{S_{in}} \quad \dots (8)$$

Another approach is to proceed with the calculation without performing the defuzzification of the criteria weights (Eq. 9). Instead, the spherical fuzzy global weights are determined using the following method:

$$\prod_{j=1}^{n} \tilde{A}_{S_{ij}} = \tilde{A}_{S_{i1}} * \tilde{A}_{S_{i2}} * \dots * \tilde{A}_{S_{in}} \quad \dots (9)$$

Interpretive Structural Modelling (ISM)

The ISM approach posits that the elements comprising a system exhibit interdependence and can be structured hierarchically. At the apex of the hierarchy lie the most crucial components, with diminishing importance observed towards the lower levels. The process of crafting a coherent mental diagram follows a systematic sequence of steps, outlined as follows:

Step 1: Develop Structural self-interaction matrix (SSIM)

To generate the SSIM matrix, experts' perspectives were gathered to delineate the relationships among the factors under consideration. Experts were tasked with comparing a single factor against another and indicating the relationship between them by selecting from four buttons provided. These relationships were then analyzed utilizing four variables to ascertain the direction of the relationship between the two factors (i and j) in the formulation of SSIM. These variables include 'V,' signifying that the ith factor endeavors to achieve the jth factor; 'A,' indicating that the jth factor strives to achieve the ith factor; 'X,' denoting mutual improvement between factors i and j; and 'O,' suggesting no discernible relation between the factors.

Step 2 and 3: Preparing initial and final Reachability Matrix (RM)

To transform SSIM into a reachability matrix, V, A, X, and O were replaced with either 1 or 0 based on specific conditions. The substitution of 1 and 0 followed the following rules:

(i) If the value of CellSSIM at row i and column j is 'V', then the value of CellRM at row i and column j is set to 1, and the value of CellRM at row j and column i is set to 0.

(ii) If the value of CellSSIM at row i and column j is 'A', then the value of CellRM at row i and column j is set to 0, and the value of CellRM at row j and column i is set to 1.

(iii) If the value of CellSSIM at row i and column j is 'X', then the value of CellRM at row i and column j is set to 1, and the value of CellRM at row j and column i is also set to 1.

(iv) If the value of CellSSIM at row i and column j is 'O', then the value of CellRM at row i and column j is set to 0, and the value of CellRM at row j and column i is also set to 0.

Following the aforementioned guidelines, the Initial Reachability Matrix (IRM) is formulated. The final iteration of the Reachability Matrix (RM), is derived subsequent to the elimination of indirect links.

Step 4: Level partitions

The formation of the reachability set involved assigning a value of 1 in the ith row, while the antecedent set was established by assigning a value of 1 in the jth column. The intersection set, comprising common factors between the reachability and antecedent sets, was computed for all factors. This intersection set determined the assignment of factors to respective levels. Initially, factors sharing similar elements in both sets were designated as level I. Subsequently, each factor was successively omitted, and the intersection set was recalculated. This iterative process continued until all factors were appropriately categorized into levels. These levels play a pivotal role in constructing the diagraph and final ISM model.

Step 5: Replacing criteria nodes with relationship and Forming ISM

Each factor is interconnected based on its relationship with other factors, forming a coherent network reflecting the interdependencies among them.

MICMAC analysis

The MICMAC analysis serves as a pivotal tool for identifying and evaluating the driving power and dependence of factors contributing to the problem or ultimate goal. Driving power is computed by summing the rows of the final reachability matrix, whereas dependence power is determined by summing the columns of the final reachability matrix. Following the MICMAC principle, predicated on matrix multiplication properties, if element X directly influences element Y (represented by X -> Y), and Y in turn influences Z (Y -> Z), then there exists an indirect influence of X on Z (X -> Z). Based on this analysis, factors are categorized into four distinct groups: Autonomous, Dependent, Linkage, and Driving.

Results and Discussion

Factor Prioritization

In the exploration of enhancing the UI/UX design for children's educational gaming platforms; several pivotal factors that significantly shape the overall user experience were uncovered. The pairwise comparison matrix is shown in Table 3. At the forefront of these considerations is age appropriateness, a cornerstone element with the highest weight (0.139) and securing the top rank (1) in the analysis as shown in Table 4. This underscores the paramount importance of tailoring content and interactions to align with the cognitive abilities and developmental stages of young users. Such alignment ensures that the educational material presented is not only engaging but also effectively comprehended and retained by the target audience. The visual design emerges as another critical component, boasting a weight of 0.102 at position 2. Visual elements, including graphics, interfaces, and animations, serve as essential tools in captivating children's attention and immersing them in the educational experience. Striking the delicate balance between aesthetically pleasing design and functional usability is imperative to maintain engagement while effectively facilitating learning objectives. Intuitive interfaces and visually stimulating environments are key to fostering exploration and interaction, thereby enhancing the overall user experience.

Moreover, the educational content itself holds

Table 3 — Spherical fuzzy pairwise comparison matrix

	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**
C1	EI	HI	SM	EI	SM	EI	EI	SM	EI	SM	HI
C2	LI	EI	HI	LI	EI	LI	LI	EI	SL	SL	SM
C3	SL	LI	EI	VL	SL	SL	EI	SM	EI	SM	HI
C4	EI	HI	VH	EI	VH	HI	VH	AM	SM	VH	VH
C5	SL	EI	SM	VL	EI	LI	EI	SL	EI	SL	SM
C6	EI	HI	SM	LI	HI	EI	SM	HI	EI	SM	EI
C7	EI	HI	EI	VL	EI	SL	EI	SM	SM	EI	EI
C8	SL	EI	SL	AL	SM	LI	SL	EI	LI	LI	VL
C9	EI	SM	EI	SL	EI	EI	SL	HI	EI	EI	SL
C10	SL	SM	SL	VL	SM	SL	EI	HI	EI	EI	LI
C11	LI	SL	LI	VL	SL	EI	EI	VH	SM	HI	EI

Table 4 — Results from the SF–AHP model

Criteria	Spherical fuzzy weights			Defuzzified values	Crisp weights	Rank
	Membership	Non-membership	Degree of hesitancy			
C1	0.573	0.368	0.318	15.599	0.101	3
C2	0.456	0.503	0.290	12.244	0.079	9
C3	0.484	0.476	0.299	13.029	0.084	8
C4	0.744	0.233	0.181	21.428	0.139	1
C5	0.456	0.489	0.319	12.072	0.078	10
C6	0.575	0.377	0.296	15.766	0.102	2
C7	0.512	0.419	0.332	13.697	0.089	5
C8	0.385	0.587	0.274	10.190	0.066	11
C9	0.503	0.423	0.339	13.385	0.087	6
C10	0.484	0.476	0.299	13.029	0.084	7
C11	0.518	0.453	0.274	14.157	0.092	4

significant weight of 0.101 and rank of 3. The quality, relevance, and diversity of educational material directly impact user engagement and the overall effectiveness of the platform as an educational tool. By offering interactive lessons, varied activities, and challenges tailored to different learning styles, designers can create a dynamic and enriching environment that encourages active participation and fosters deep learning experiences. Rich, engaging content not only sustains user interest but also facilitates knowledge acquisition and retention, ultimately driving the educational efficacy of the gaming platform.

Moving beyond content and design, considerations such as background score, accessibility, and usability play pivotal roles. Background score, with a weight of 0.092 and ranked fourth, contributes to immersion and reinforces educational concepts within gaming experiences. Thoughtfully curated soundtracks complement gameplay, enriching the overall user experience and enhancing engagement. Usability, ranked fifth with a weight of 0.089, plays a vital role in facilitating smooth navigation and interaction. User-centric design principles prioritize simplicity and efficiency, empowering children to explore educational content effortlessly. Intuitive controls, clear instructions, and responsive feedback mechanisms enhance usability, optimizing user engagement and learning outcomes.

Additionally, safety and privacy considerations, with a weight of 0.087 and ranked sixth, are paramount for building trust among parents and educators. Establishing a secure digital environment instils confidence, fostering prolonged engagement and supporting positive learning experiences. Similarly, ensuring accessibility, with a weight of 0.084 and ranked eights, is imperative for accommodating diverse user needs and preferences. Intuitive navigation, inclusive design practices, and support for various devices and platforms promote equal participation and learning opportunities for all children.

Each of these factors, from age appropriateness to visual design, educational content, and beyond, contributes to the holistic design of children's educational gaming platforms. By prioritizing these aspects, designers can create immersive and effective learning environments that cater to the unique needs and capabilities of young users. Through thoughtful integration of age-appropriate content, engaging visuals, accessible interfaces, and robust safety measures, educational gaming platforms can inspire curiosity, promote active participation, and foster meaningful learning experiences among children.

Factors' Interrelationships

The process of forming the Structural Self-Interaction Matrix (SSIM) involved soliciting input from multiple experts, who provided their individual

Table 5 — Structural self interaction matrix (SSIM)

Criteria	1	2	3	4	5	6	7	8	9	10	11
C1	–	V	V	A	V	V	O	V	V	O	V
C2		–	A	A	A	A	A	V	V	O	A
C3			–	A	A	A	X	A	O	A	A
C4				–	V	V	O	O	O	O	O
C5					–	X	X	V	O	V	O
C6						–	V	A	V	A	X
C7							–	V	V	X	V
C8								–	O	O	O
C9									–	A	O
C10										–	V
C11											–

Table 6 — Final reachability matrix

Criteria	1	2	3	4	5	6	7	8	9	10	11	Driving Power
C1	1	1	1	0	1	1	1	1	1	1	1	10
C2	0	1	1	0	0	1	0	1	1	0	0	5
C3	0	1	1	0	1	0	1	1	1	1	1	8
C4	1	1	1	1	1	1	1	1	1	1	1	11
C5	0	1	1	0	1	1	1	1	1	1	1	9
C6	0	1	1	0	1	1	1	1	1	1	1	9
C7	0	1	1	0	1	1	1	1	1	1	1	9
C8	0	1	1	0	1	1	1	1	1	0	1	8
C9	0	0	0	0	0	0	0	0	1	0	0	1
C10	0	1	1	0	1	1	1	1	1	1	1	9
C11	0	1	1	0	1	1	1	1	1	0	1	8
Dependence power	2	10	10	1	9	9	9	10	11	7	9	87

Table 7 — Level partitioning

Criteria	Reachability set	Antecedent set	Level
C1	1,2,3,5,6,7,8,9,10,11,	1,4,	VI
C2	2,3,6,8,9,	1,2,3,4,5,6,7,8,10,11,	II
C3	2,3,5,7,8,9,10,11,	1,2,3,4,5,6,7,8,10,11,	II
C4	1,2,3,4,5,6,7,8,9,10,11,	4,	V
C5	2,3,5,6,7,8,9,10,11,	1,3,4,5,6,7,8,10,11,	III
C6	2,3,5,6,7,8,9,10,11,	1,2,4,5,6,7,8,10,11,	III
C7	2,3,5,6,7,8,9,10,11,	1,3,4,5,6,7,8,10,11,	III
C8	2,3,5,6,7,8,9,11,	1,2,3,4,5,6,7,8,10,11,	II
C9	9,	1,2,3,4,5,6,7,8,9,10,11,	I
C10	2,3,5,6,7,8,9,10,11,	1,3,4,5,6,7,10,	IV
C11	2,3,5,6,7,8,9,11,	1,3,4,5,6,7,8,10,11,	III

Table 8 — MICMAC Ranking

Criteria	Factors/problems	Dependence power	Driving power	Driving/Dependence power	MICMAC rank
C1	Educational content	2	10	5.00	2
C2	Engagement	10	5	0.50	10
C3	Accessibility	10	8	0.80	8
C4	Age appropriateness	1	11	11.00	1
C5	Interactivity	9	9	1.00	4
C6	Visual design	9	9	1.00	4
C7	Usability	9	9	1.00	4
C8	Feedback mechanisms	10	8	0.80	8
C9	Safety and privacy	11	1	0.09	11
C10	Cross-platform compatibility	7	9	1.29	3
C11	Background score	9	8	0.89	7

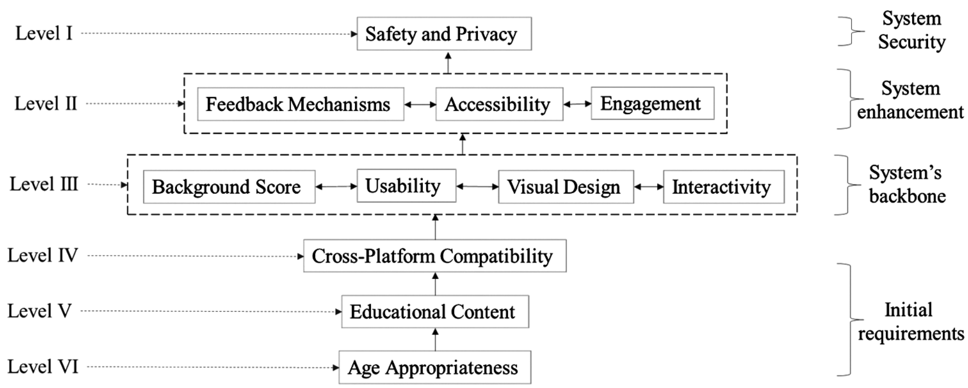

Fig. 3 — ISM model

mappings based on their expertise. The iterative process enabled the gradual formation of the final SSIM (Table 5). The final reachability matrix (Table 6) was derived by eliminating transitive links among the factors. Level Partitioning (Table 7) outlines the categorization of factors into distinct levels, likely based on their significance or impact within the system under study. Each level likely represents a different tier of importance or influence, with factors grouped accordingly. The data in Table 8 presents the ranking of factors, likely based on their importance, relevance, or impact within the context of the system being analyzed.

The research findings unveil the hierarchical significance and interplay among various pivotal factors (Figs 3 & 4). Foremost among these is 'Age appropriateness,' ranked first in both dependence and driving power, and occupying a prominent position within the Driving group. This underscores its fundamental role in shaping educational content frameworks. Following closely is 'Educational content,' positioned at rank two in MICMAC analysis, boasting substantial dependence power and driving power. Its classification within the Driving group further accentuates its influential status within the system. Conversely, factors such as 'Engagement' and 'Safety and privacy,' despite their essential roles, exhibit lower driving powers, placing them within the Dependence group. Additionally, factors like 'Usability,' 'Interactivity,' 'Accessibility, ' 'Feedback mechanisms, ' 'Cross-platform compatibility,' and 'Background score' demonstrate moderate driving powers and are

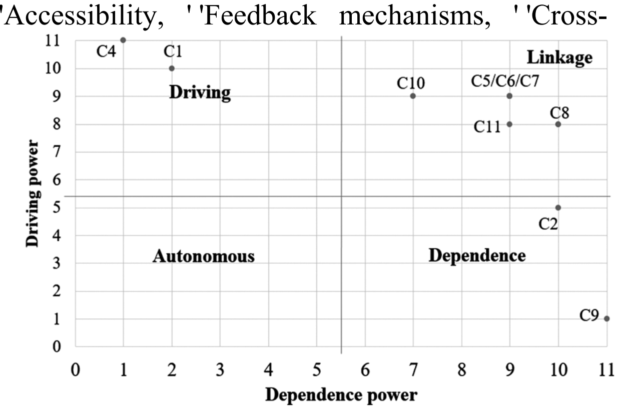

Fig. 4 — MICMAC analysis

categorized within the Linkage group. This classification highlights their interconnected contributions to the educational ecosystem. Moreover, the hierarchical partitioning of these factors, with 'Age appropriateness' at Level V and others distributed across Levels II to IV, elucidates their structural significance within the ISM hierarchy. These nuanced insights gleaned from the rank-based analysis provide a comprehensive understanding of the dynamics governing educational content, offering actionable pathways for strategic enhancements and targeted interventions to optimize learning environments effectively.

Practical Implications

The practical implications based on the analysis emphasize the need to prioritize "Age appropriateness" and "Educational content" in the development of educational games, ensuring alignment with curriculum objectives and relevance to the target age group. Enhancing "Visual design" and "Usability" through intuitive interfaces and engaging visuals is the key to maintaining learner engagement. Additionally, optimizing "Cross-platform compatibility" and carefully selecting background music can enhance accessibility and immersion across devices. Although factors like "Interactivity," "Accessibility," "Safety and privacy," "Engagement," and "Feedback mechanisms" rank lower, they play a vital role in creating a secure, inclusive, and interactive learning experience. A holistic approach, integrating collaboration among content developers, designers, and UX experts, is essential for delivering comprehensive and impactful UI/UX design in educational games.

Conclusions

This research offers valuable insights into the critical factors influencing user experience on children's educational gaming platforms. By employing an Integrated Multicriteria Decision Making Framework, the study emphasizes the importance of age-appropriate content and interactions that align with children's cognitive development. Key elements identified for optimizing UI/UX include visual design, educational content, background score, usability, safety, privacy, and accessibility. The ISM model highlights the hierarchical significance of these factors, prioritizing 'Age appropriateness' and 'Educational content,' followed by 'Visual design' and 'Usability.' Practical recommendations focus on improving cross-platform compatibility, optimizing background scores, and enhancing interactivity, accessibility, and privacy. While the study relies on expert input, which may introduce bias, and does not address technological constraints, it provides a strong framework for decision-making in UI/UX design. Future research should incorporate direct feedback from children and explore emerging technologies like AR and VR to improve engagement and learning outcomes on these platforms.

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